POLISHING METHOD AND POLISHING APPARATUS USED FOR THE SAME

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The present invention relates to a method for polishing side faces of grooves formed on a workpiece, and to an apparatus used for the same.

2. Description of the Related Art

[0002] A method for polishing a cross-section of a workpiece with a polishing element, and an apparatus used for the same, are disclosed in Japanese Unexamined Patent Application Publication No. 2001-277110, and shown in Figs. 5A and 5B.

[0003] Referring to Fig. 5A, the apparatus described in the above patent document has a combined tool 54 including a cylindrical pedestal (i.e., hub) 541, a circular cutting blade 542 disposed at a periphery of one side of the pedestal 541, and a circular polishing wheel 543 disposed at a periphery of the other side of the pedestal 541.

[0004] The combined tool 54 is installed on a rotary spindle 56 by fitting the pedestal 541 to a mount 57 disposed on the rotary spindle 56 and by screwing a clamp nut 58 onto a screw bolt formed around the periphery of one end of the mount 57.

[0005] The method for cutting and polishing a workpiece (or a rectangular workpiece 11) by the apparatus will now be described.

[0006] The method for cutting and polishing described in the above-mentioned patent document includes a step of cutting, a step of polishing a first cross-section, and a step of polishing a second cross-section.

[0007] Step of cutting

According to the step of cutting the rectangular workpiece 11, the rectangular workpiece 11 is cut into a bar-shaped workpiece 111 and a remaining rectangular workpiece 11 with the cutting blade 542 of the combined tool 54. A chuck table 33 having a workpiece holding element 35, which fixes the rectangular

workpiece 11, is moved in the feeding direction, i.e., in the direction indicated by an arrow X in Figs. 5A and 5B, thereby cutting the rectangular workpiece 11 held by the chuck table 33 along a predetermined cutting line by the cutting blade 542 of the combined tool 54.

[0008] Step of polishing a first cross-section

Referring to Fig. 5A, the polishing wheel 543 of the combined tool 54 attached to the rotary spindle 56 is applied to a cross-section of the remaining rectangular workpiece 11, which is adhered to a second workpiece fixture 362. The cross-section is polished so that the surface of the cross-section has a roughness of 20 nm or less.

[0009] Specifically, the combined tool 54 is moved in the directions indicated by arrows Y and Z in Fig. 5A to adjust its position. The side face of the polishing wheel 543 of the combined tool 54 attached to the rotary spindle 56 is located at the position corresponding to the cross-section of the remaining rectangular workpiece 11. Then the chuck table 33 is moved in the direction indicated by the arrow X in Fig. 5A. Accordingly, the cross-section of the remaining rectangular workpiece 11 adhered to the second workpiece fixture 362, which is fixed on a second fixing part 353, is polished.

[0010] Step of polishing a second cross-section

After the step of polishing the first cross-section, the chuck table 33, i.e., a vacuum chuck 332 including the workpiece holding element 35 is rotated by 180 degrees. As in the step of polishing the first cross-section, the polishing wheel 543 of the combined tool 54 attached to the rotary spindle 56 is applied to a cross-section of the bar-shaped workpiece 111, which is adhered to a first workpiece fixture 361 fixed on a first fixing part 352. The cross-section is polished so that the surface of the cross-section has a roughness of 20 nm or less.

[0011] Furthermore, in a typical method for polishing an end face of a strip prepared by cutting a wafer, the wafer is cut in advance with a cutter having a peripheral cutting edge, and then the resultant wafer strip is fixed with a fixture and polished with a lapping machine and a polishing machine.

[0012] According to the method described in the above-mentioned patent document, the position of the polishing wheel 543 is adjusted by moving the polishing wheel 543 in the thrust direction of a main spindle so as to secure a predetermined distance for polishing. Then the chuck table 33 is moved in the direction indicated by the arrow X in Figs. 5A and 5B, thereby polishing the workpiece. Since the workpiece is polished during cutting at the peripheral surface of the polishing wheel 543, abrasive grains on the polishing wheel 543 become deeply embedded in the workpiece. Unfortunately, the workpiece therefore becomes susceptible to damage, for example, due to cracks and dislocations. Accordingly, chipping seriously damages the workpiece and the polished surface does not have a satisfactory flatness.

[0013] As described above, a wafer is cut with a cutter and the resultant wafer strip may be polished with the lapping machine and the polishing machine. This method includes a cutting process, a lapping process, and a polishing process. Accordingly, additional operations, such as cleaning and fixing of the workpiece, are required in every process, and additional equipment is also required for those operations. Unfortunately, therefore, the processing cost increases. Furthermore, this method requires experience and skill, and the consistent manufacturing of a uniform polished surface is difficult to achieve.

SUMMARY OF THE INVENTION

[0014] In view of the above problems the present invention provides a method for polishing a workpiece without chipping it, so as to have a superiorly flat surface, and an apparatus used for the same.

[0015] In order to achieve the above object, a first aspect of the present invention provides a method for polishing side faces of grooves formed on a workpiece, the method including a first step of forming the grooves on the workpiece with a cutting blade; a second step of inserting a polishing element into one of the grooves, the width of the polishing element being smaller than that of the grooves, by vertically moving at least one of the workpiece and the polishing element; a third step of putting a main surface of the polishing element into contact with a side face of the groove by

horizontally moving at least one of the workpiece and the polishing element; and a fourth step of sliding the polishing element along the groove by moving at least one of the workpiece and the polishing element to polish the workpiece by relative movement between the workpiece and the polishing element and by urging the main surface of the polishing element toward the side face of the groove.

[0016] In the third step, a contact position of the polishing element to the workpiece may be detected by measuring the load on the polishing element, and in the fourth step, the moving conditions of at least one of the workpiece and the polishing element may be determined using the contact position of the polishing element to the workpiece as a reference, so that polishing is performed over a predetermined distance.

[0017] A second aspect of the present invention provides an apparatus for polishing side faces of grooves formed on a workpiece, the apparatus including a fixture for fixing the workpiece; a rotating main shaft disposed in a horizontal direction of the fixture; a rotating driving unit for rotating the rotating shaft; a disc polishing element having abrasive grains thereon for polishing the side faces of the grooves, the polishing element being fixed to the rotating shaft; a driving unit for driving at least one of the rotating shaft and the workpiece in the vertical direction of the rotating shaft, in the horizontal direction of the rotating shaft, and in the direction along the side face of the grooves; and a detector for detecting the position where the polishing element is in contact with the workpiece.

[0018] According to the first aspect of the present invention, a method for polishing side faces of grooves formed on a workpiece includes a first step of forming the grooves on the workpiece with a cutting blade; a second step of inserting a polishing element into one of the grooves, the width of the polishing element being smaller than that of the grooves, by vertically moving at least one of the workpiece and the polishing element; a third step of putting a main surface of the polishing element into contact with a side face of the groove by horizontally moving at least one of the workpiece and the polishing element; and a fourth step of sliding the polishing element along the groove by moving at least one of the workpiece and the polishing

element to polish the workpiece by relative movement between the workpiece and the polishing element and by urging the main surface of the polishing element toward the side face of the groove, i.e., by movement along the longitudinal direction of the rotating shaft as described below. Accordingly, the side faces of the workpiece can be polished by using the polishing element to grind off a portion of each side face to a very shallow depth. The method does not seriously damage the workpiece and prevents chipping of the workpiece, thereby polishing the workpiece sufficiently.

[0019] According to the first aspect of the present invention, the polishing element is inserted in one of the grooves so as not to contact the side face (i.e., end face) of the groove on the workpiece and is fixed in position, and then the polishing element is moved in the thrust direction of the rotating shaft. Accordingly, the method does not seriously damage the workpiece and prevents chipping of the workpiece. Furthermore, the workpiece can be reliably polished and the polished surface is remarkably flat and has superior wear resistance.

[0020] In the present invention, the grooves include two kinds of grooves: a groove formed by fully cutting through a workpiece, i.e., a groove composed of two opposed side faces; and a groove formed by partially cutting through a workpiece. In the present invention, the side faces of the groove also include two kinds of side faces: side faces formed by full cutting; and side faces of the groove formed by partial cutting.

[0021] According to the method of the present invention, in the third step, a contact position where the polishing element contacts the workpiece may be detected by measuring the load on the polishing element, and in the fourth step, the moving conditions of at least one of the workpiece and the polishing element may be determined using the contact position of the polishing element and the workpiece as a reference, so that polishing is performed over a predetermined distance. This method allows the polishing element to move in the thrust direction of the rotating shaft at a constant speed or with a constant load. Accordingly, the method does not seriously damage the workpiece and prevents chipping of the workpiece, thereby polishing the workpiece accurately.

[0022] The polishing apparatus according to the second aspect of the present invention reliably performs the polishing method of the present invention. As a result, chipping of the workpiece can be prevented, thereby polishing the workpiece accurately.

[0023] The polishing apparatus includes a driving unit for driving the rotating shaft in the vertical direction of the rotating shaft, in the horizontal direction of the rotating shaft, and in the direction along the side face of the grooves. The driving unit may be composed of three driving units: a first driving unit for driving the rotating shaft in the vertical direction of the rotating shaft; a second driving unit for driving the rotating shaft in the horizontal direction of the rotating shaft; and a third driving unit for driving the rotating shaft in the direction along the side face of the grooves. The driving unit may also be composed of either one driving unit or two driving units to drive the rotating shaft in the vertical direction of the rotating shaft, in the horizontal direction of the rotating shaft, and in the direction along the side face of the grooves.

[0024] For the driving unit, the model and the specific construction are not especially limited and various known driving units used in the field of the present invention may be used.

[0025] The present invention can be widely applied to, for example, a manufacturing process for electronic components including a process for polishing side faces of grooves formed on a workpiece, which may for example be a wafer or a substrate.

[0026] Other features and advantages of the present invention will become apparent from the following description of embodiments of the invention which refers to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0027] Fig. 1 is a schematic block diagram of the main structure of a polishing apparatus according to an embodiment of the present invention;

[0028] Fig. 2 illustrates a state where a polishing stone is inserted in a groove in a step of a polishing method according to an embodiment of the present invention;

[0029] Fig. 3 illustrates a state where the polishing stone contacts with a side face of a workpiece in a step of the polishing method according to the disclosed embodiment of the present invention;

[0030] Fig. 4 illustrates a state where the polishing stone is further moved in the direction of the side face of the workpiece from a contact position of the polishing stone to the side face of the workpiece in a step of the polishing method according to the disclosed embodiment of the present invention; and

[0031] Figs. 5A and 5B are perspective views showing a polishing method using a known polishing apparatus.

DESCRIPTION OF EMBODIMENTS OF THE INVENTION

[0032] The features of the present invention will now be described in detail with reference to the following embodiments.

[0033] Polishing apparatus

Fig. 1 is a schematic block diagram of the main structure of a polishing apparatus for performing a polishing method of the present invention.

[0034] The polishing apparatus includes a fixture (or a table) 22 for fixing a workpiece (or a wafer) 21; a rotating shaft 23, for example, a main shaft of a cutter with a peripheral cutting edge, such as a dicer or a slicer; a rotating driving unit (or a motor) 24 for rotating the rotating shaft 23; a disc cutting stone (or a cutting blade) 26 having abrasive grains thereon for polishing side faces of grooves 21a (see Fig. 2 to Fig. 4) of the wafer 21, the cutting stone 26 being fixed to the rotating shaft 23; a disc polishing stone (or a polishing element) 27 having a diameter and a thickness smaller than those of the cutting stone 26, the polishing stone 27 having abrasive grains thereon; a first driving unit 28 for driving the rotating shaft 23 in the vertical direction; a second driving unit 29 for driving the rotating shaft 23 in the horizontal direction of the rotating shaft; a third driving unit 30 for driving the rotating shaft 23 in the direction along the side face of the grooves; and a detector 31 for detecting the position where the polishing stone 27 is in contract with the wafer 21.

[0035] As described below, the detector 31 can precisely detect the position where the polishing stone 27 is in contact with the wafer 21 by monitoring the electrical energy of the rotating driving unit (or the motor) 24. The detector 31 according to this embodiment includes an inverter 41; three-phase power cables 42 connecting the inverter 41 and the motor 24; a sensor (or Hall element) 43 wound around one cable 42a of the three-phase power cables 42; a contact detector 44 in which a threshold is set for determining whether the polishing stone 27 contacts with the wafer 21 or not according to the electrical energy in the cable 42a; and a control element 45 for controlling the operation of, for example, the rotating shaft 23 in response to a signal from the contact detector 44 in the case where the electrical energy in the cable 42a exceeds the threshold set in advance in the contact detector 44.

[0036] In the detector 31, the load change in the motor 24 causes fluctuation of the detection level in the sensor 43. If the detection level in the sensor 43 exceeds the threshold set in advance in the contact detector 44, a trigger signal indicating a skip mode is sent to the control element 45.

[0037] According to this method, the contact position can be detected with a precision of ±0.0004 mm.

[0038] In a system including the detector 31, although the electrical energy in the rotating driving unit (motor) 24 is monitored as described above, in an alternative arrangement the current flowing in the motor 24 may be monitored.

[0039] The cutting stone 26 and the polishing stone (i.e., polishing element) 27 used in the polishing apparatus according to this embodiment are as follows:

(a) Cutting stone

External diameter: 80 mm

Thickness: 0.5 mm

SD#4000 (made by electroforming)

(b) Polishing stone (polishing element)

External diameter: 76 mm

Thickness: 0.4 mm

SD#4000 (made by resin bonding) (base metal: thickness 0.3 mm)

[0040] Polishing method

An example of a method for cutting the wafer 21 (thickness: 0.5 mm) and polishing side faces of the wafer 21 using the polishing apparatus will now be described with reference to the drawings.

[0041]

(1) The wafer 21 was cut at a predetermined pitch by vertically moving the cutting stone 26, which was disposed at a predetermined position for cutting, to form grooves 21a.

The conditions for the process were as follows:

Feeding rate: 1 mm/s

Cutting depth: 0.8 mm from the surface of the wafer

Rotation speed of revolutions of the main shaft: 15,000 rpm

[0042]

(2) The rotating shaft 23 was moved in the horizontal direction, thereby positioning the polishing stone 27 over one of the grooves 21a. The polishing stone 27 was moved vertically such that the bottom of the periphery of the polishing stone 27 was disposed substantially at the central area in the width direction of the grooves 21a, and at a position 0.7 mm in depth from the surface of the wafer 21. Referring to Fig. 2, the polishing stone 27 was disposed so as not to contact either side face 21b of the groove 21a, or the fixture (i.e., table) 22.

[0043]

(3) Referring to Fig. 3, the rotating shaft 23, to which the polishing stone 27 was fixed, was moved in the direction of the shaft (i.e., in the direction indicated by an arrow A in Fig. 3), thereby putting the main surface of the polishing stone 27 into contact with one side face 21b of the groove 21a.

[0044] The detector 31 detected the position where the polishing stone 27 was in contact with and the wafer 21.

[0045]

(4) The wafer 21 was polished while controlling the distance, i.e., the amount, of the polishing according to the method described below.

[0046] After the contact position of the polishing stone 27 and the wafer 21 was detected, the polishing stone 27 was returned to the previous position where the polishing stone 27 did not contact the side face 21b of the groove 21a, i.e., the position at the central area in the width direction of the groove 21a. Then the polishing was started again from the contact position.

[0047] Specifically, referring to Fig. 4, the polishing stone 27 was fed at a low speed in the direction of polishing, i.e., in the direction indicated by an arrow A in Fig. 4, by a constant distance G (G=about 10 μm) from the position (i.e., an initial point) where the polishing stone 27 contacted the wafer 21 again. When the polishing stone 27 was moved in the direction indicated by an arrow A by the constant distance and reached an end point, the feed of the polishing stone 27 was stopped. Then honing was performed on the wafer 21 by a spark-out for 30 seconds. The spark-out means the polishing stone 27 was moved along the side face of the groove 21b without moving in the horizontal direction of the rotating shaft 23, i.e., without moving in the direction indicated by the arrow A, thereby polishing the side face of the groove 21b. The direction for moving along the side face 21b of the groove 21a may be in the longitudinal direction or in the vertical direction of the side face of the wafer 21. Furthermore, the polishing stone 27 may be moved such that the rotating shaft 23 reciprocates, thereby allowing the polishing stone 27 to have both rotary motion and reciprocating motion.

[0048] According to the above embodiment, after the contact position of the polishing stone 27 and the wafer 21 was detected, the polishing stone 27 was returned to the previous position where the polishing stone 27 did not contact the side face 21b of the groove 21a. The reason for this is as follows: In a slicer, the peripheral cutting edge has a small thickness and is susceptible to deformation. In that case, the polishing stone 27 needs to return to the previous position where the polishing stone 27 does not contact the side face 21b of the groove, and is then fed at a low speed in the horizontal direction by a constant distance (about 10 μm) from the contact position, i.e., the initial point; otherwise, the detected load fluctuates, and accordingly, the polishing distance, i.e., the polishing amount, cannot be precisely controlled.

[0049] According to the polishing process of the embodiment, the feed rate (i.e., the moving speed along the side face 21b of the groove) was 1 mm/sec., and the rotation speed of the main shaft was 2,000 rpm.

[0050] The polishing stone 27 may be moved at a higher speed until the polishing stone 27 comes into contact with the wafer 21.

[0051] In this embodiment, the diameter of the wafer 21 was larger than the distance between the polishing stone 27 and the cutting stone 26 (see Fig. 1). Accordingly, first, the polishing was performed from a side face 21b of one groove disposed at one end of the wafer 21 to a side face 21b of a groove disposed at the center of the wafer 21. Then the wafer 21 was rotated by 180 degrees and the side faces 21b disposed at the remaining half portion of the wafer were polished.

[0052] The side faces 21b had mirror-finished surfaces after polishing as described above.

[0053]

(5) The side face 21b disposed at the opposite side of the groove 21a was polished as in the same method and the same conditions described in (3) above and in (4) above.

[0054]

(6) The polishing stone 27 was moved to the subsequent groove 21a and the processes (2), (3), (4), (5) described above were repeated. The processes (2), (3), (4), (5) were repeated according to the number of the grooves 21, thereby polishing all the side faces 21b.

[0055] As described above, wafer strips having side faces 21b with mirror-finished surfaces were manufactured.

[0056] According to the polishing method of the above embodiment, a single polishing apparatus having the wafer mounted on the fixture allows the wafer to be cut into the desired number of wafer strips, and allows the side faces of the wafer strips to be effectively and reliably polished. According to the polishing apparatus and the polishing method described in the embodiment, the side faces can be readily and

accurately polished so that the side faces have mirror-finished surfaces (i.e., a surface roughness Ra of 10 nm or less, and chipping of 100 nm or less).

[0057] Furthermore, according to the embodiment, the polished surface has superior flatness because the polishing method includes the honing process.

[0058] The honing process also essentially uses the cutting action of the abrasive grains disposed on the polishing stone. However, the honing process reliably allows the polished surface to be flat and to have superior wear resistance, for the reasons described below:

[0059]

(a) The honing process is performed at lower speed and lower pressure than those in other general polishing processes; therefore, a damaged layer caused by the polishing process has a small thickness.

[0060]

(b) In the polishing process (i.e., honing process), the cutting speed in the direction of the rotating shaft to which the polishing stone is fixed is, in general, about 0.5 μm/min. to 10 μm/min., and the polishing stone contacts the workpiece in a plane. Accordingly, the pushing force on each abrasive grain and the heat caused by polishing are small, thereby preventing surface deterioration.

[0061] In a typical known polishing process, since the cutting depth of the abrasive grains is on the order of 100 nm or more, the polishing seriously damages the workpiece. Accordingly, serious chipping occurs at the edge of the side faces of the grooves. On the other hand, according to the polishing method of the present invention, the cutting depth of the abrasive grains can be on the order of 10 nm or less. Accordingly, the damage to the workpiece by polishing is decreased, thereby preventing serious chipping at edge portions of the side face.

[0062] Although the rotating shaft having the polishing element is moved in the above embodiment, the workpiece (or a wafer) may be moved instead. Furthermore, both the rotating shaft, to which the polishing stone is fixed, and the workpiece (or a wafer) may be moved so as to move both positions relatively.

[0063] Although the cutting stone 26 and the polishing stone 27 are attached to the same rotating shaft 23 in the above embodiment, the cutting stone 26 and the polishing stone 27 may be attached to separate rotating shafts.

[0064] Furthermore, a grindstone having both cutting and polishing functions may be used for the cutting stone and the polishing stone.

[0065] The grindstone having both cutting and polishing functions includes, for example, a grindstone having abrasive grains for cutting at the peripheral face and the border area between the peripheral face and both main faces, and having abrasive grains for polishing at both main faces.

[0066] According to the embodiment, a driving unit for driving the rotating shaft having the polishing element includes the first driving unit, the second driving unit, and the third driving unit. The first driving unit drives the rotating shaft in the vertical direction, the second driving unit drives the rotating shaft in the horizontal direction of the rotating shaft, and the third driving unit drives the rotating shaft in the direction along the side faces of the grooves. However, the driving unit may be composed of one driving unit or two driving units as long as the rotating shaft can be driven in the vertical direction, in the horizontal direction, and in the direction along the side face of the grooves.

[0067] The present invention is not limited to the above embodiments. Various applications and modifications are possible within the scope of the present invention with regard to the kind of the workpiece, the dimensions of the workpiece, the dimensions of the groove, the kind of polishing element, moving conditions for the polishing element and the workpiece during the polishing process (for example, the moving distance, the moving speed, and the moving direction).

[0068] Although the present invention has been described in relation to particular embodiments thereof, many other variations and modifications and other uses will become apparent to those skilled in the art. Therefore, the present invention is not limited by the specific disclosure herein.